Economics of Waste Conversion

Chemical Conversion via Modular Manufacturing: Distributed, Stranded, and Waste Feedstocks

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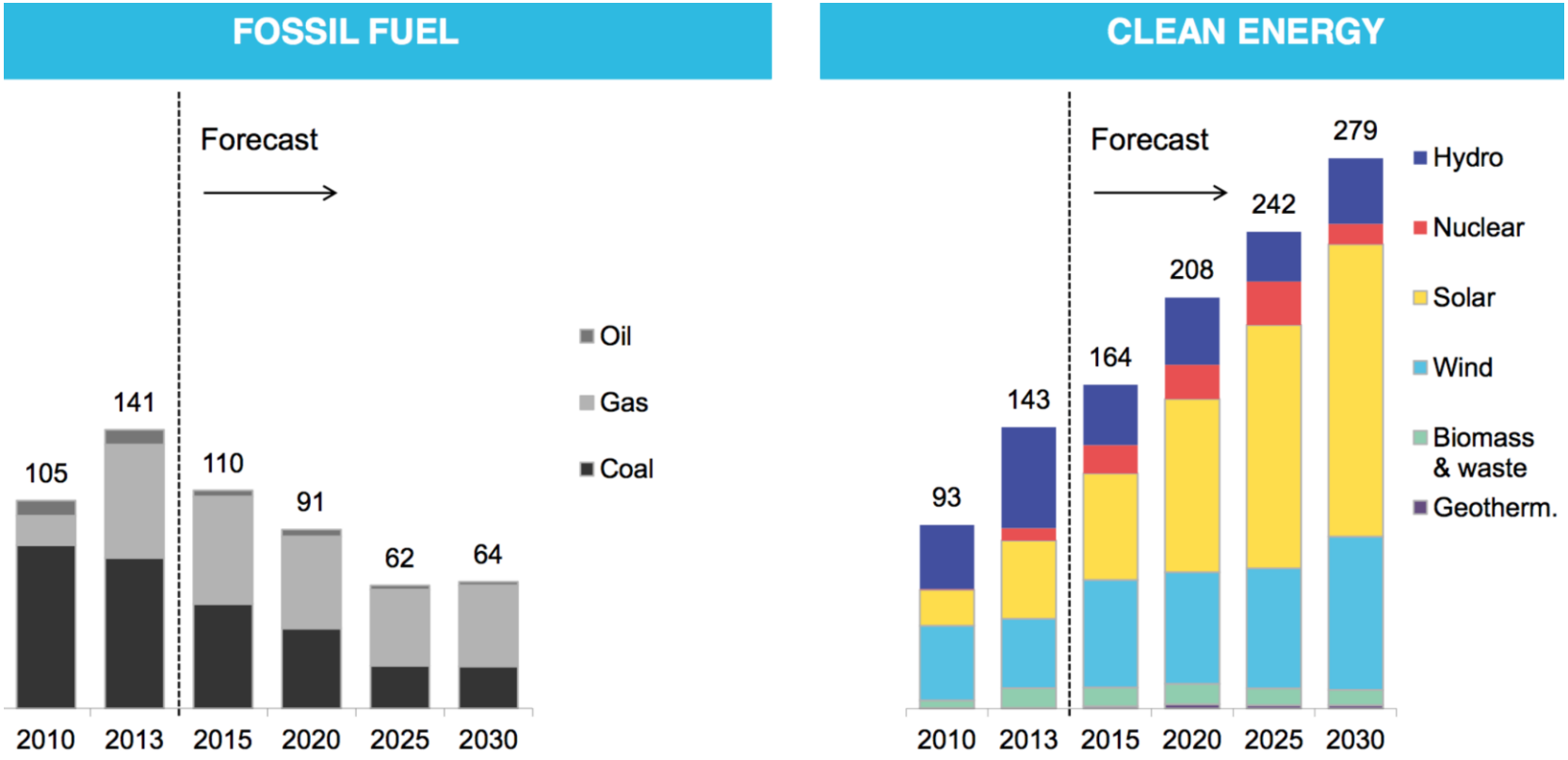
Map Credit: Brown and Brown, Why Are We Producing Biofuels? Winter 2011.

BREAKTHROUGH ENERGY COALITION

"Our primary goal with the Coalition is as much to accelerate progress on clean energy as it is to make a profit" – Bill Gates



Power generation capacity additions (GW)

Bloomberg New Energy Finance

Economics of Waste Conversion

Low energy density

Highly distributed or stranded

Of low (perceived) value

Of high untapped potential

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Economic lessons from the solar, wind, and ethanol industries

- Experience curves: every doubling of production reduces capital costs by a fixed percentage
- System optimization: operating costs decrease through learning-by-doing
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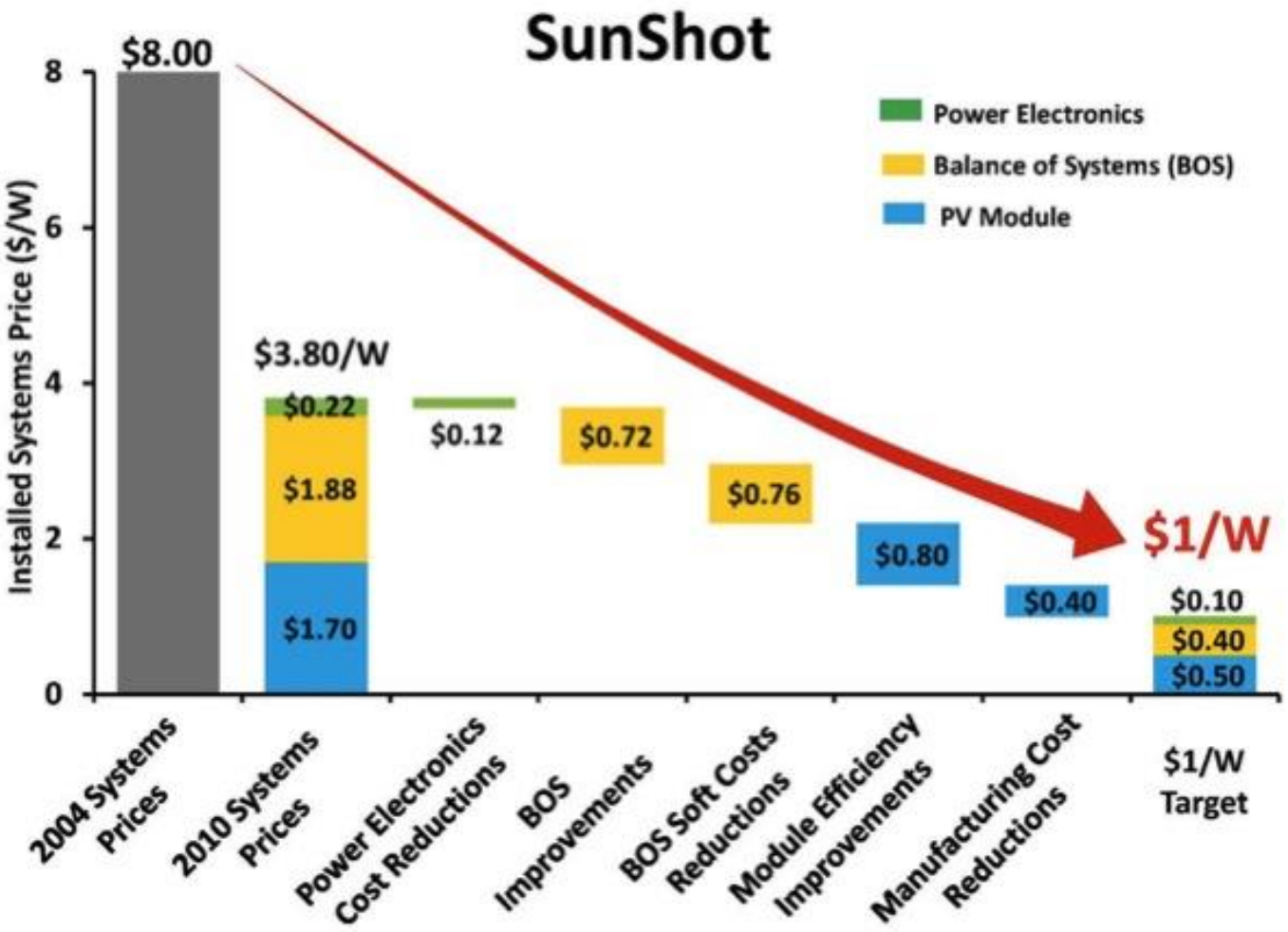
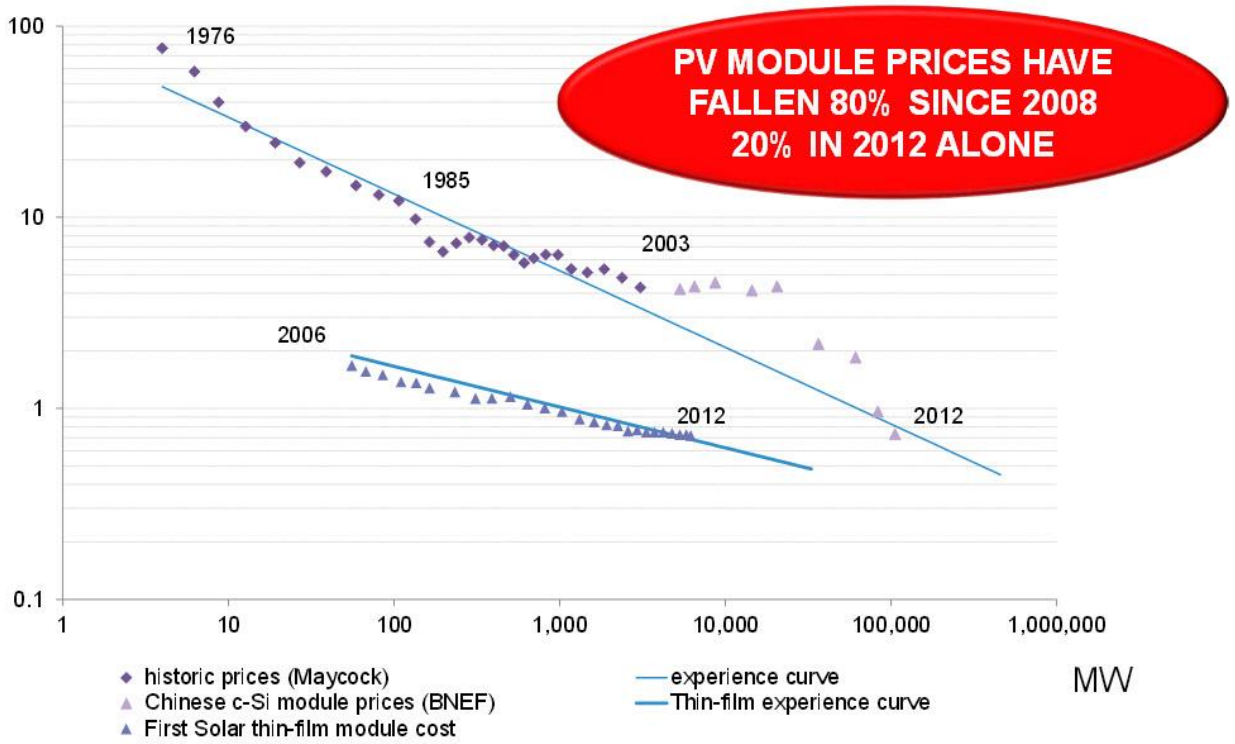


Cost breakdown of installed PV

Source: DoE "The Dollar-a-Watt Program".

Solar Energy Manufacturing

PV EXPERIENCE CURVE, 1976-2012
2012 $/W

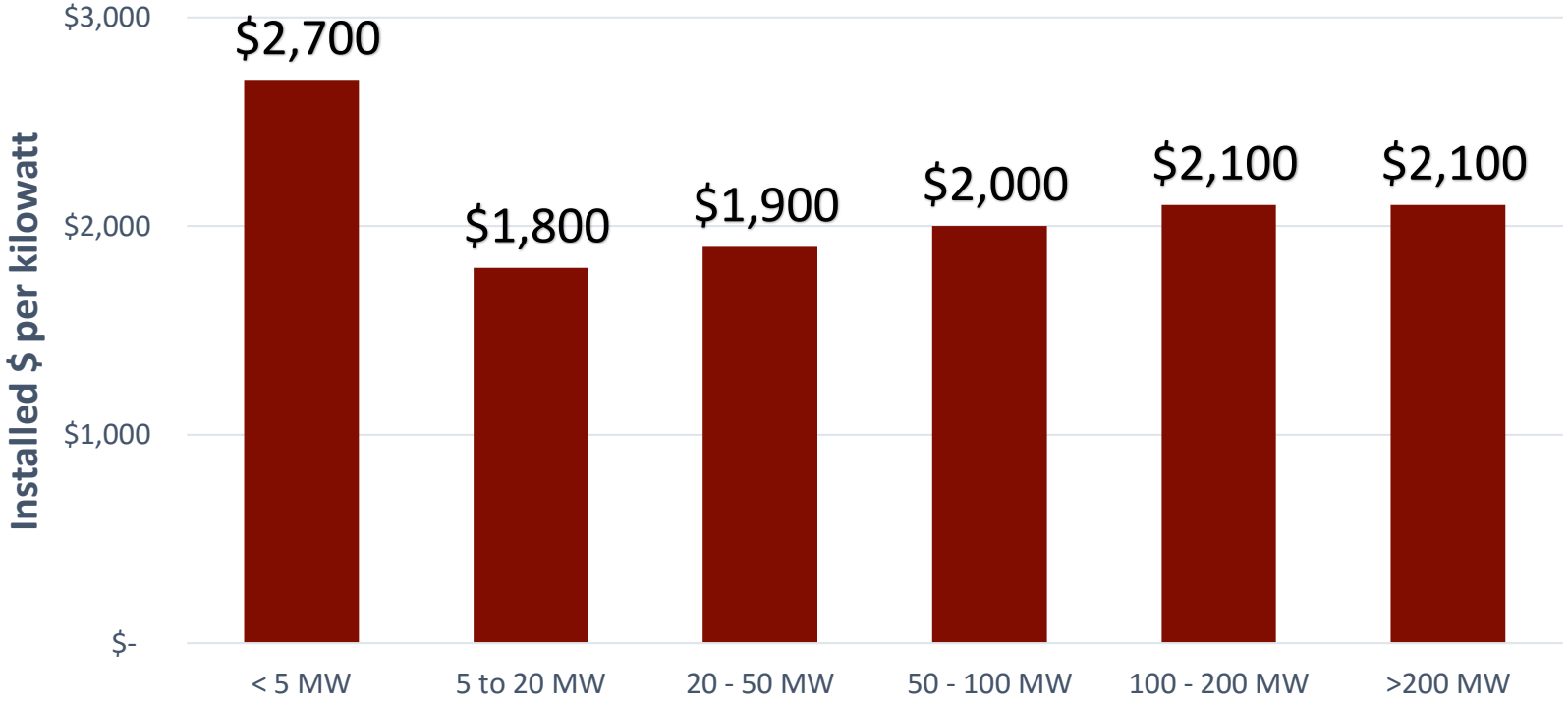


Note: Prices inflation indexed to US PPI.

Source: Paul Maycock, Bloomberg New Energy Finance

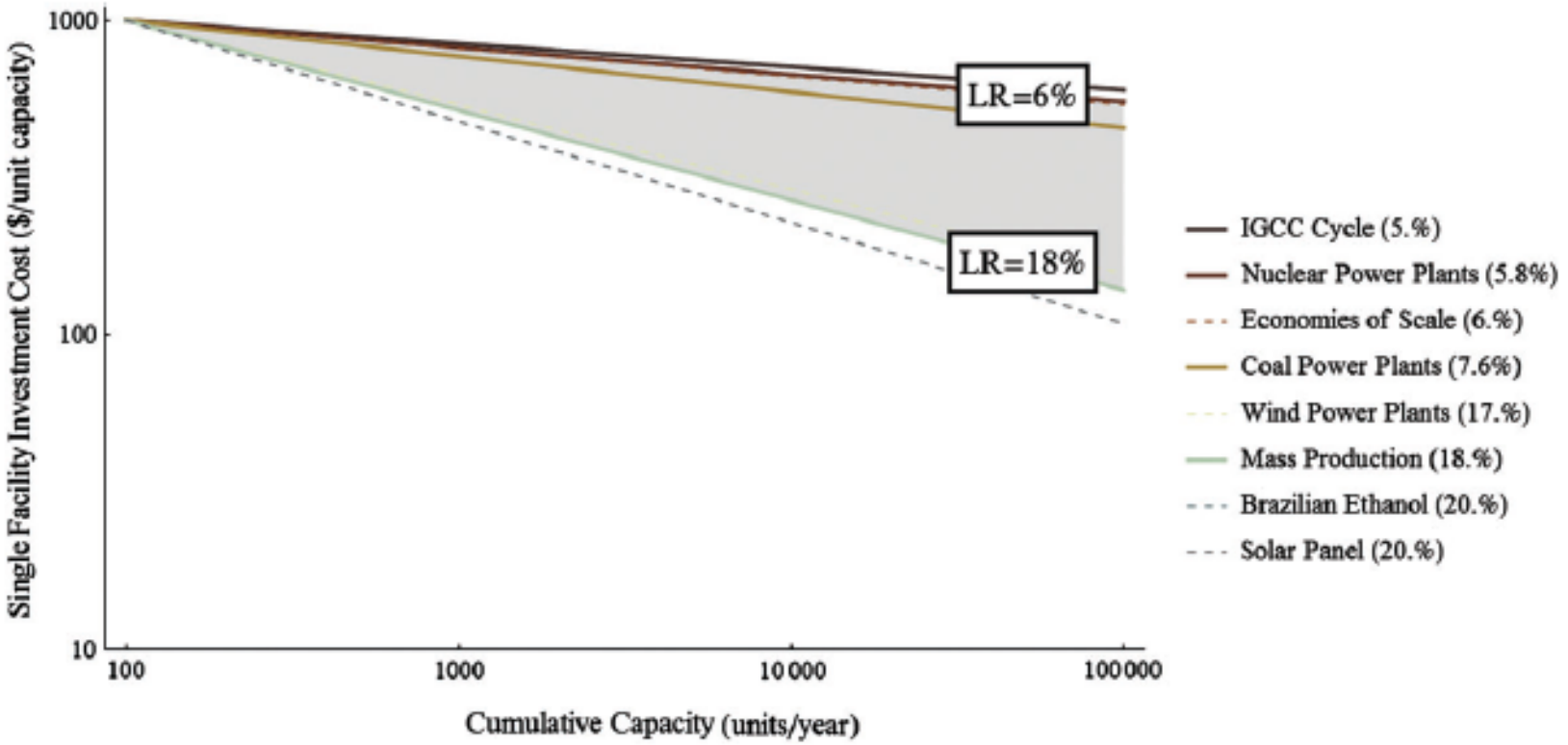
Wind Energy Manufacturing

Wind power projects indicate ‘sweet’ spot for wind farms (5 – 20 MW)



Source: 2009 Wind Technologies Market Report. U.S. DOE

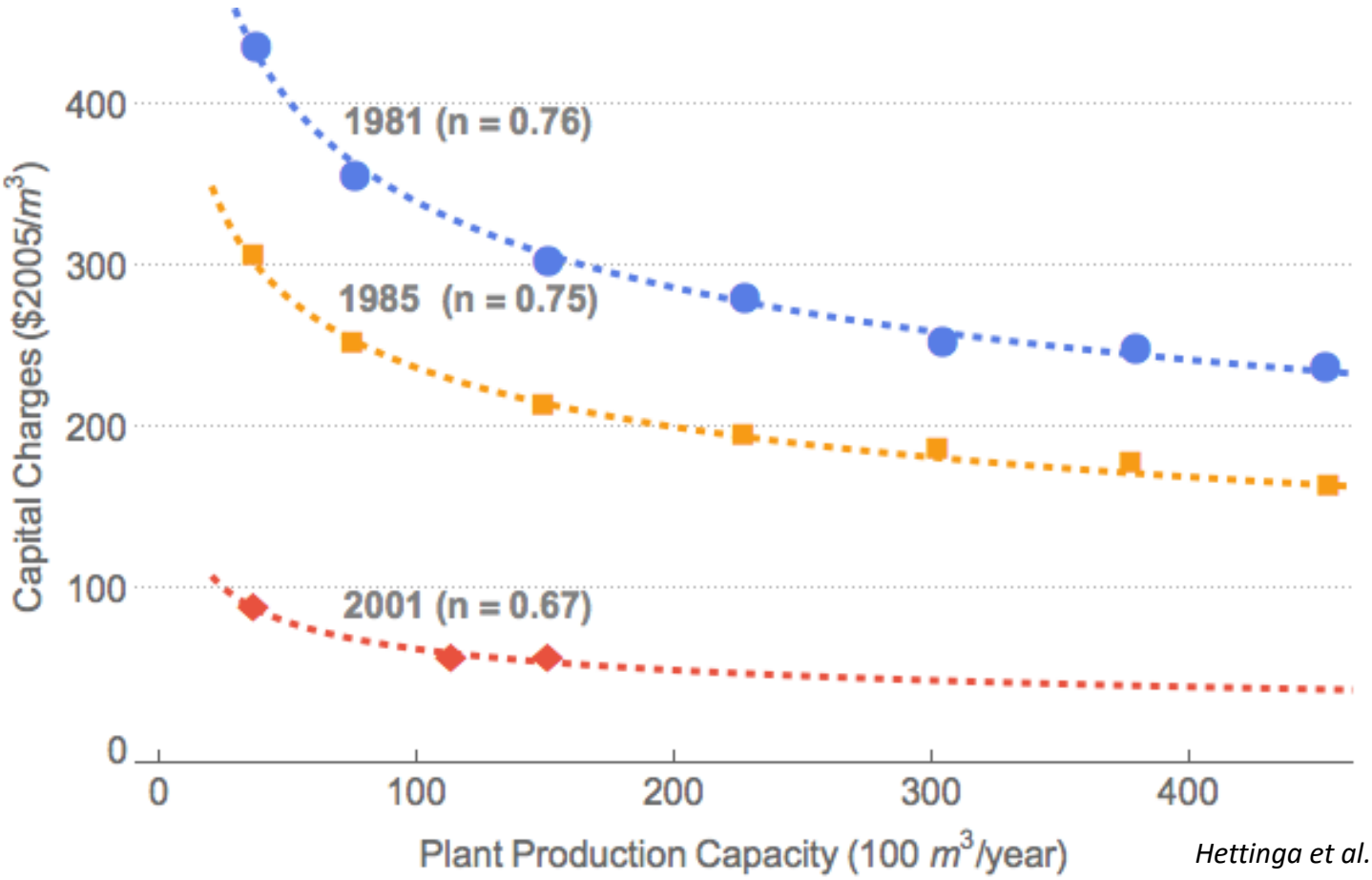
Learning Rates Across Industries



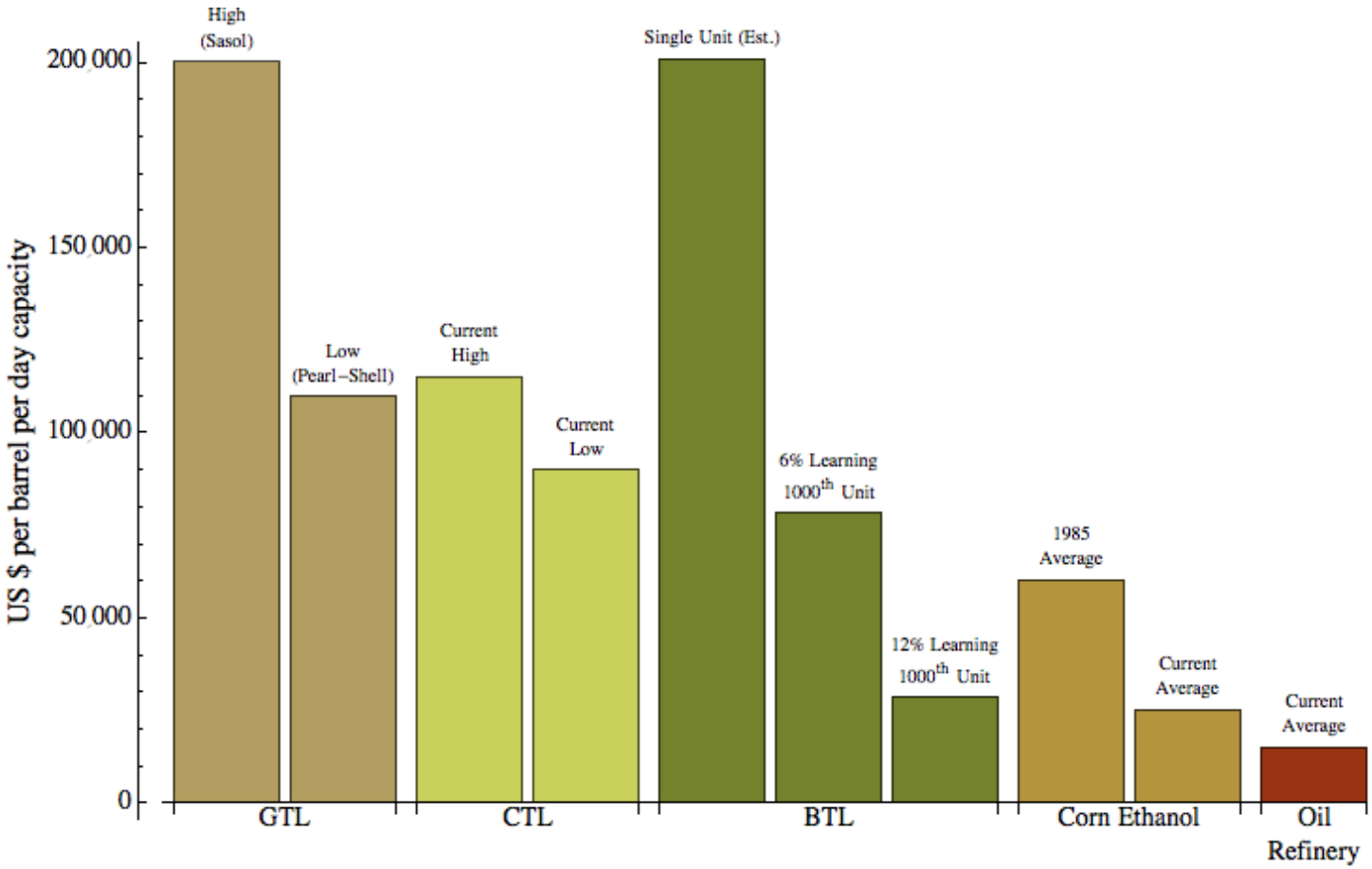
Industries that adopt mass production have learning rates of 18% vs. 6% for economies-of-scale

Daugaard et al. 2014

Historical Ethanol Capital Cost Trends in the US



Hettinga et al. 2009



G(Gas), C(Coal), and B(Biomass)-to-Liquids

How do we increase learning rates of waste conversion?

Could small, modular, distributed systems unlock biofuels' potential?

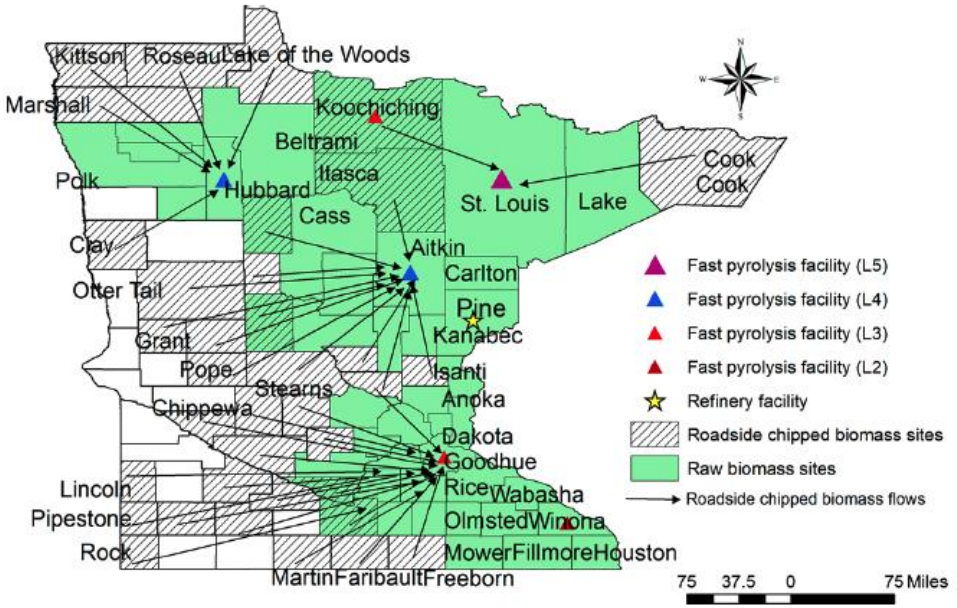
Manufacturing-based cost reductions

Increased proximity to resources and consumers

Reduced costs of relocation

Increased resilience of distribution networks

Improved feedstock/product compatibility



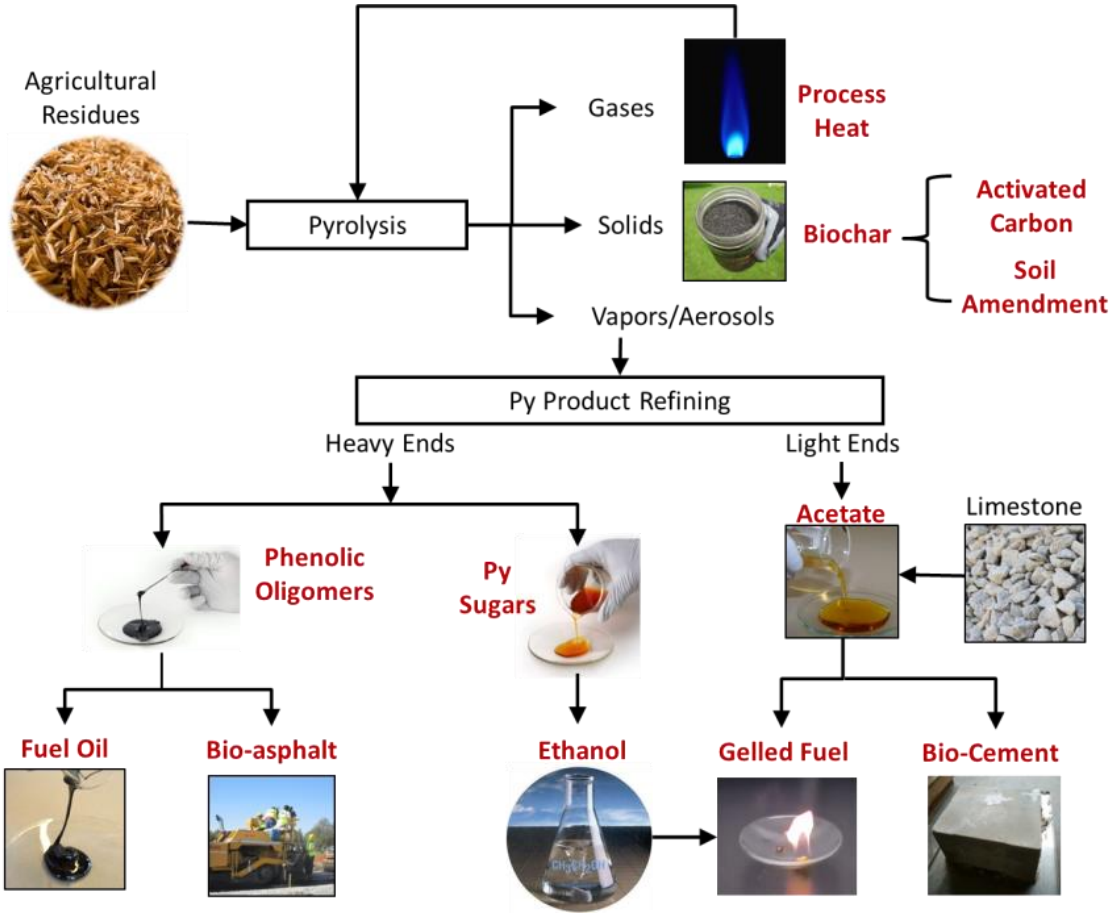
Zhang & Wright 2014

The Fast Pyrolysis Platform

Fast pyrolysis enables small scale (200 ton per day) production of:

- Hydrocarbon chemicals,
- Alternative biochemicals, and
- Fuels

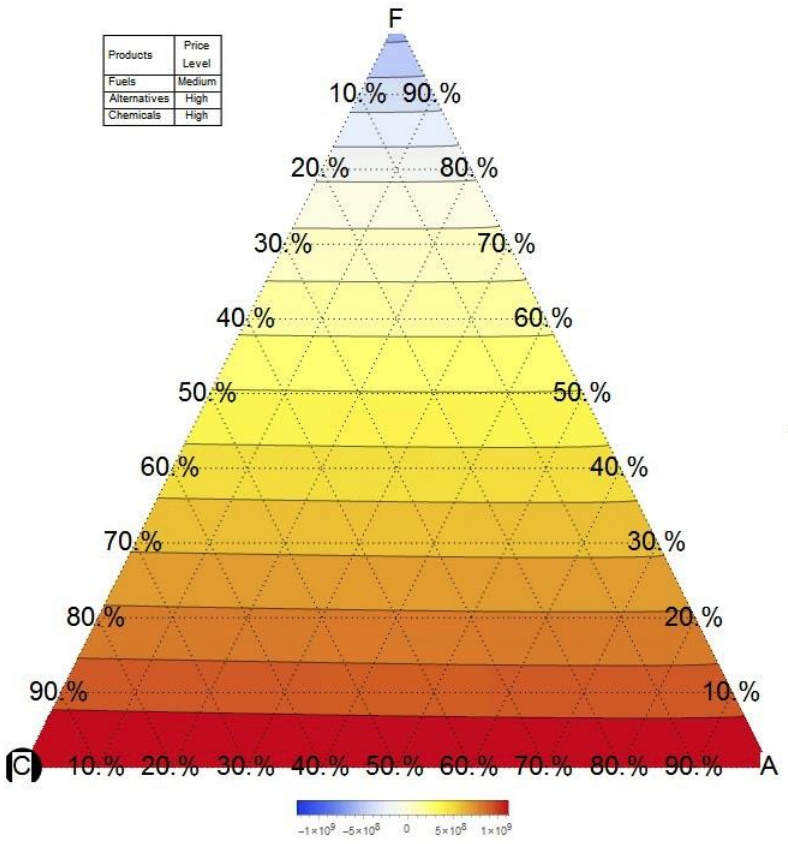
- Biochar for carbon sequestration
- Biochar for soil amendment



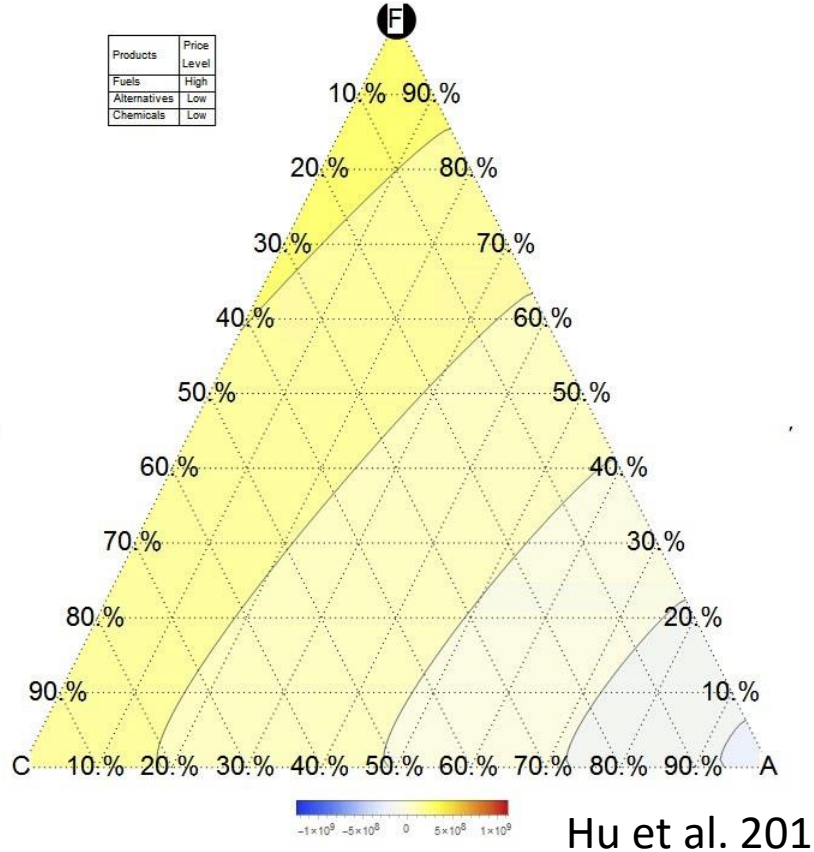
Courtesy of: Brown

Market-Based Product Portfolios

High Priced Chemicals Market



Low Priced Chemicals Market



Hu et al. 2015

Bio-oil co-firing fuel (BCF)

Fluidized bed pyrolyzer at ISU

Bio-char

Land application of bio-char

- Providing nutrients
- Improving water retention capacity
- Reducing soil bulk density

Bio-oil
(heavy end fraction)

Coal

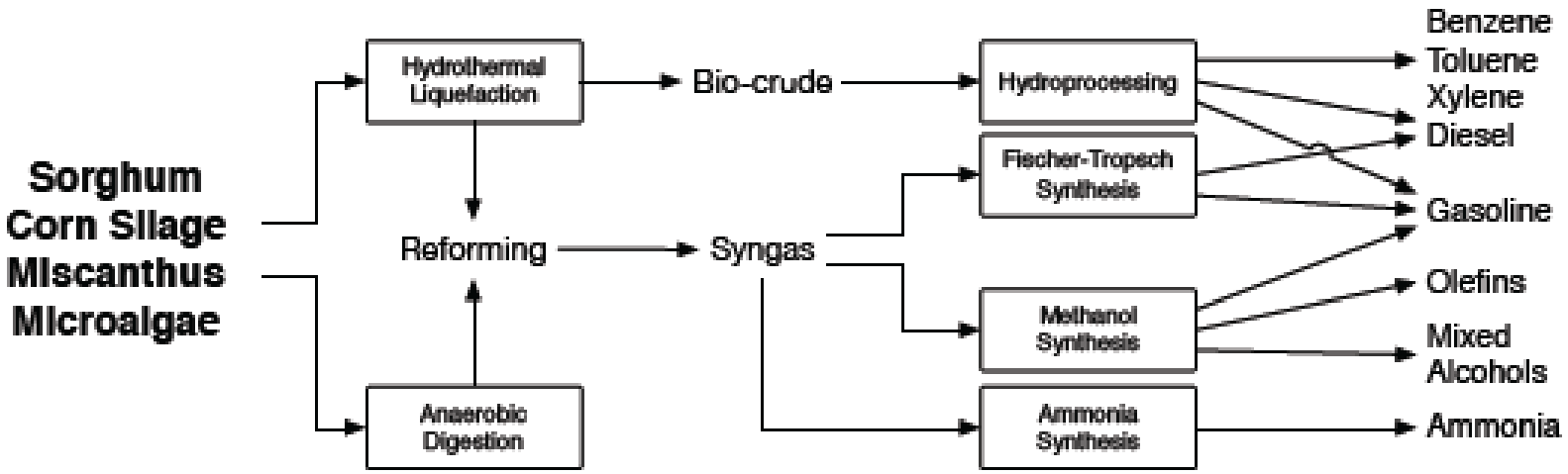
Bio-oil co-firing fuel

- Overcoming biomass and coal co-firing limits
- Without usual problems of boiler derating and ash fouling

BCF power meets Clean Power Plan Coal plant emissions reductions at a cost of ¢9.81/kWh

Dang et al. 2015

Wet Feedstock Conversion



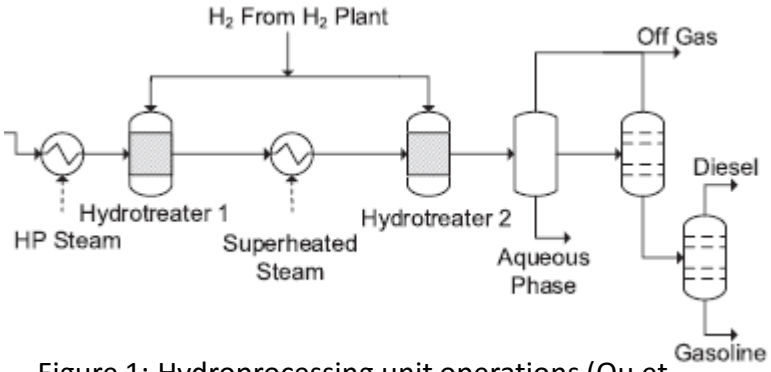


Figure 1: Hydroprocessing unit operations (Ou et al. 2014)

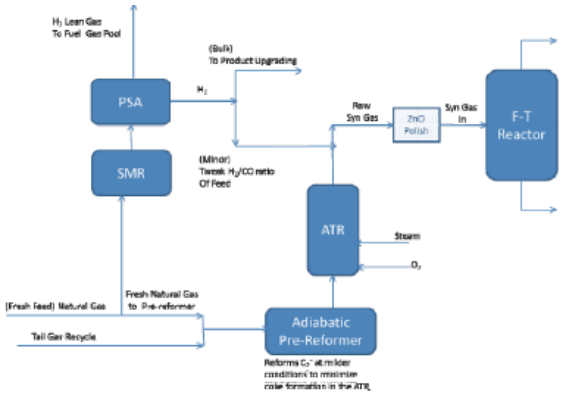
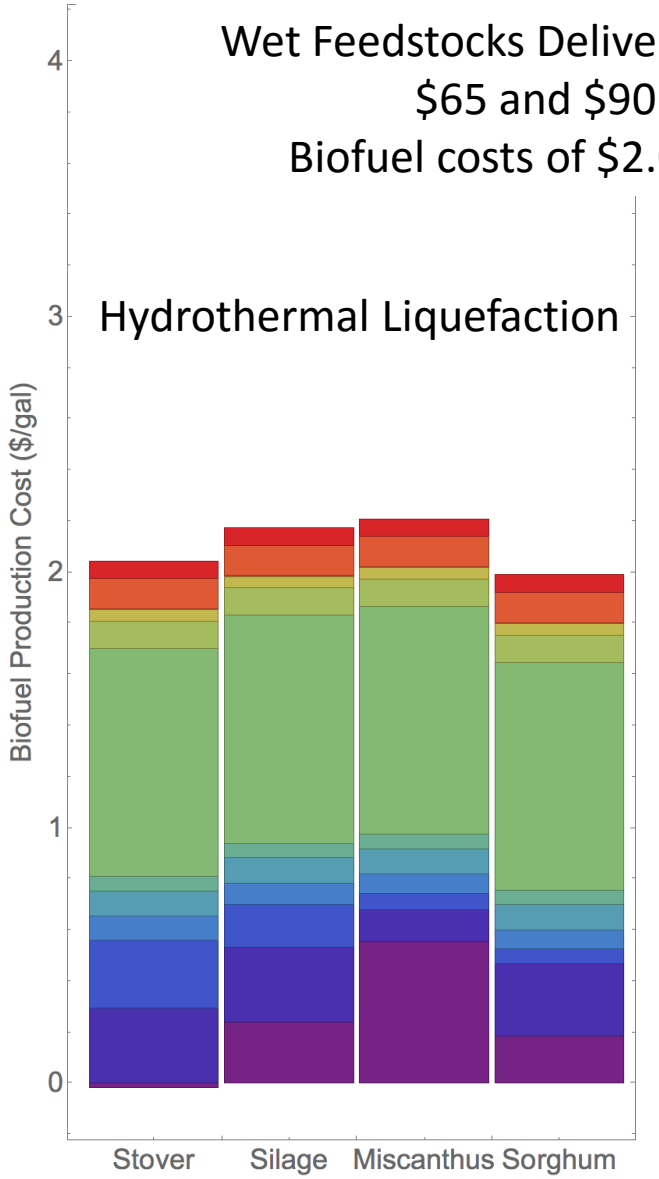
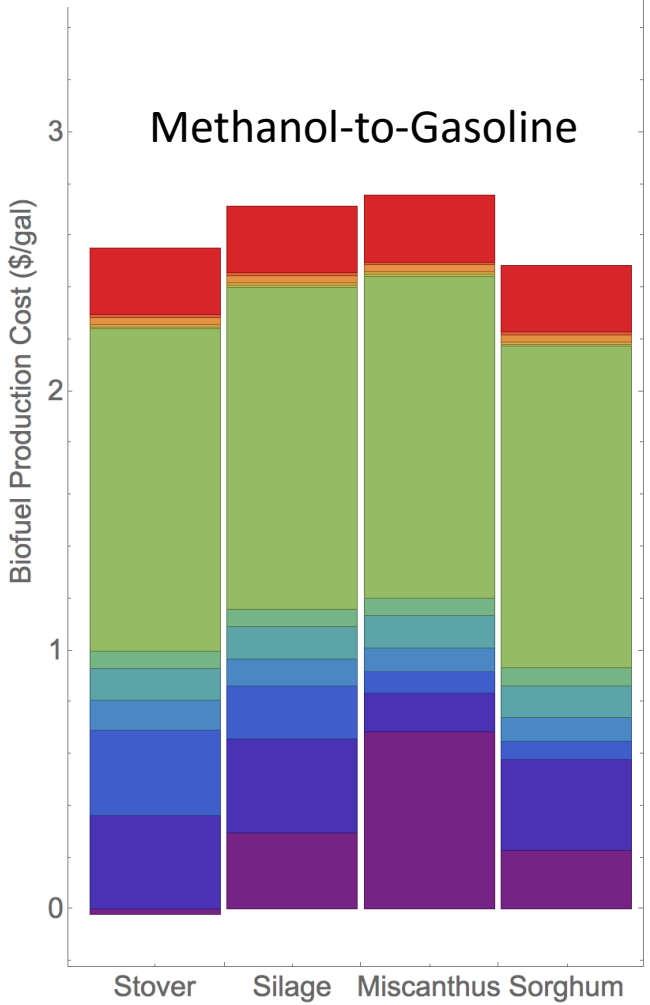


Figure 2: Fischer-Tropsch Synthesis unit operations (Goellner et al., NETL 2013)

Wet Feedstocks Delivered Costs Range between $65 and $90 per tonne with Biofuel costs of $2.00 to $3.00 per gallon





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Acknowledgments

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NSF EPSCoR

Department of Energy

http://www.biorenew.iastate.edu/research/signature/energymfg/

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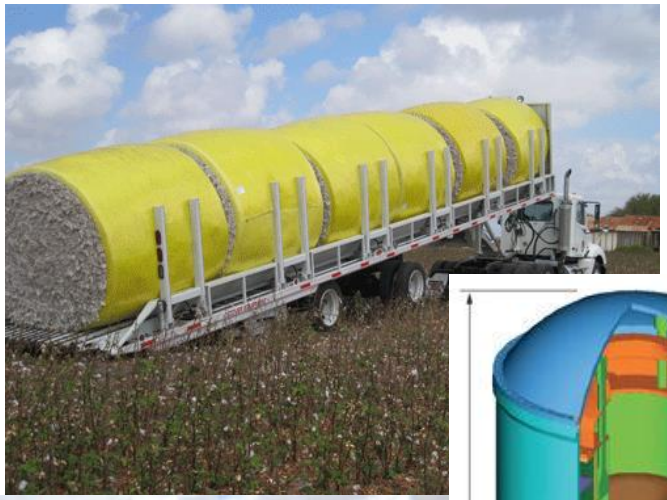
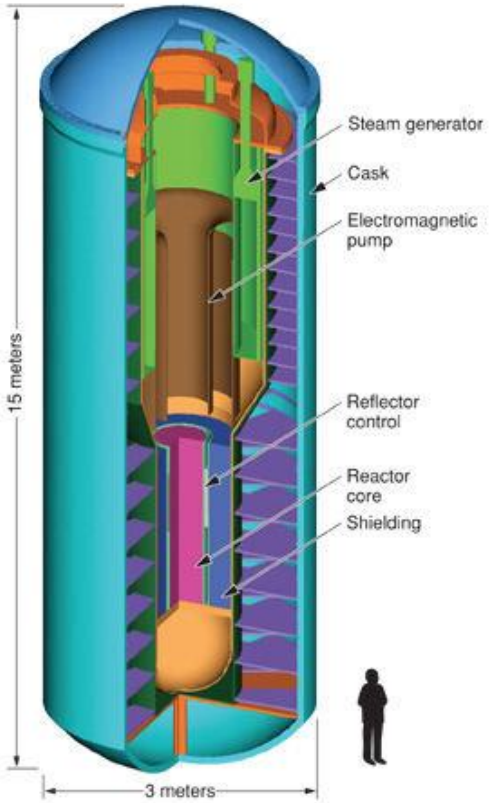
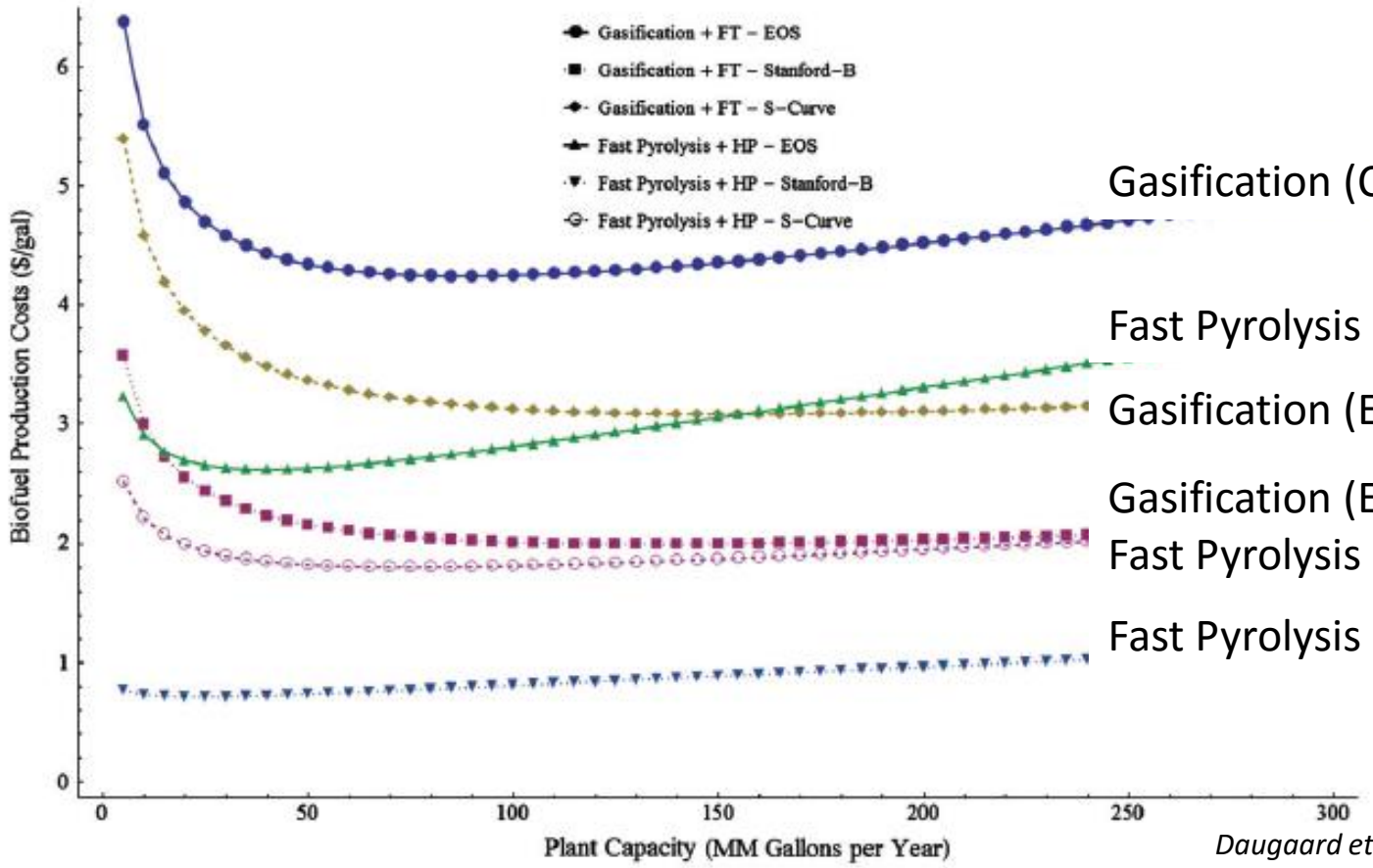
Benefits of Small Modular Design

- Locational flexibility
- Investment flexibility
- Operational flexibility
- Management flexibility





Learning Rates



Gasification (Curr.)

Fast Pyrolysis (Curr.)

Gasification (Est.)

Gasification (Est.)

Fast Pyrolysis (Est.)

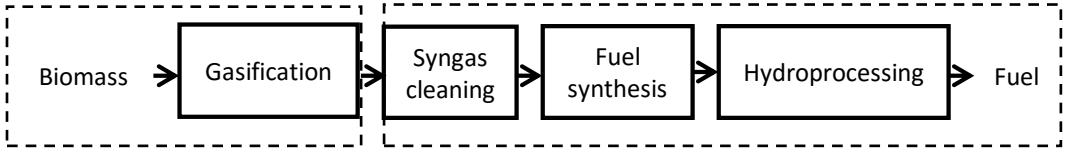
Fast Pyrolysis (Est.)

Daugaard et al. 2014

Levels of Biofuel Pathway Experience

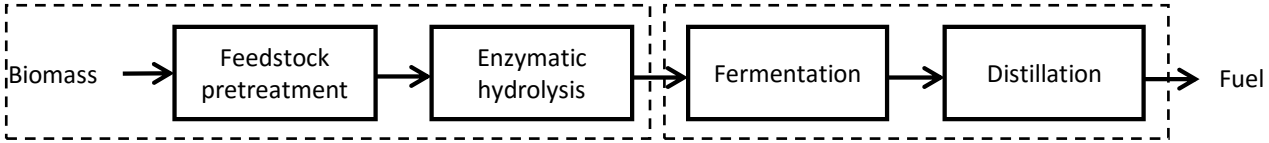
Date of First Commercial-scale Implementation

Gasification and F-T synthesis



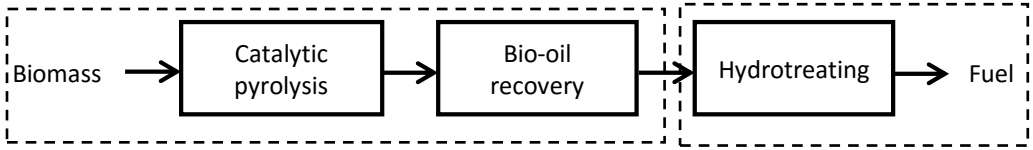
N/A *1940s*

Cellulosic ethanol via enzymatic hydrolysis



N/A *1980s*

Catalytic pyrolysis and hydrotreating



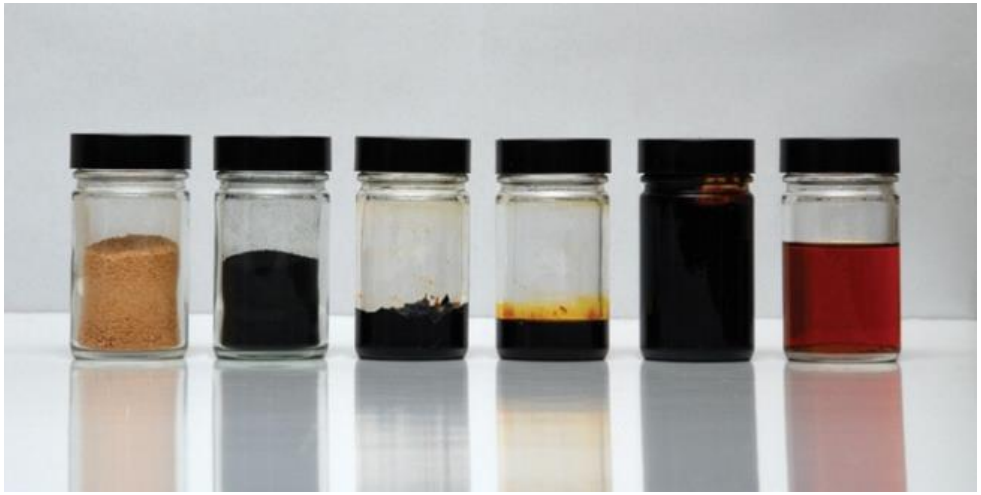
2012 *1920s*

Engineering Design

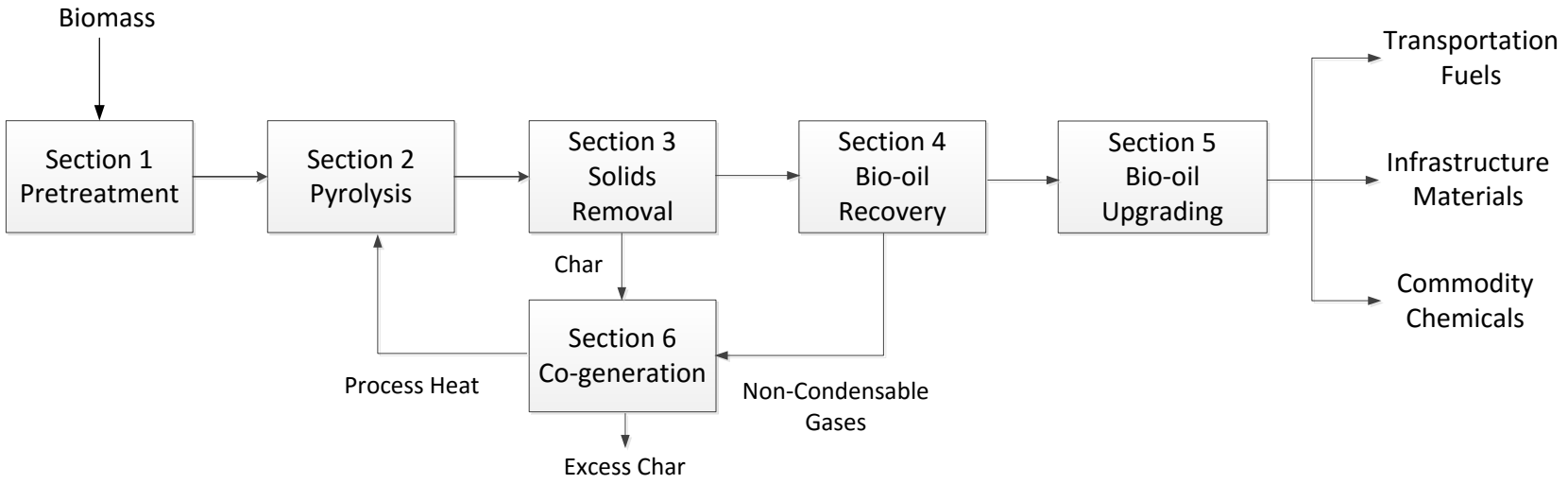
Small modular designs enable novel platforms and products.

The engineering challenge differs from large-scale systems:

- Design for manufacturability
- Lean manufacturing
- Resource sustainability

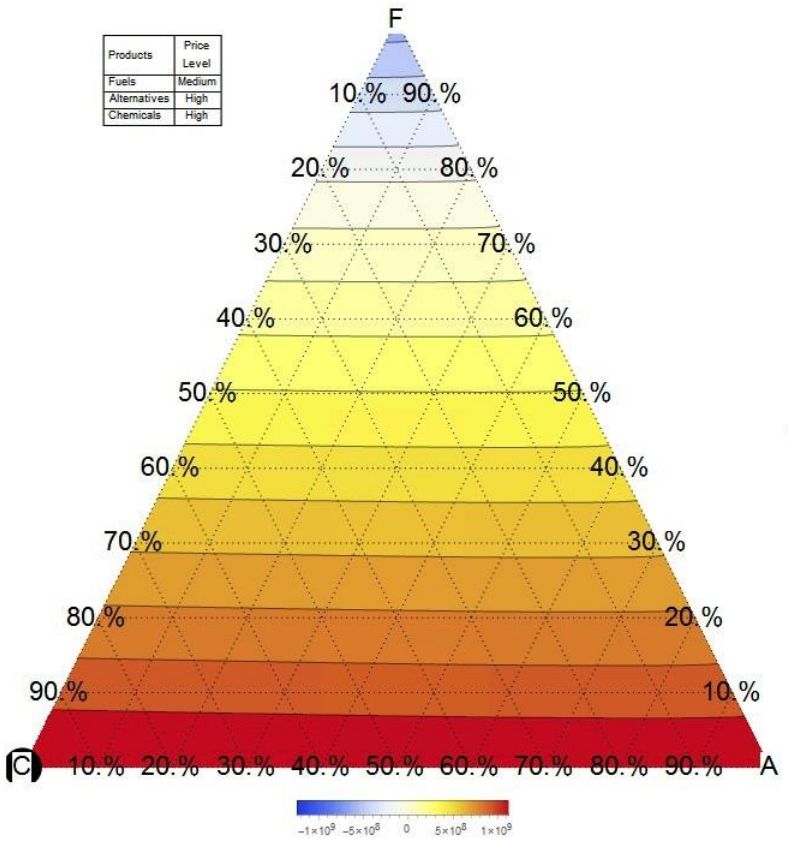


Engineering Design



Engineering Design Market Analysis

High Priced Chemicals Market



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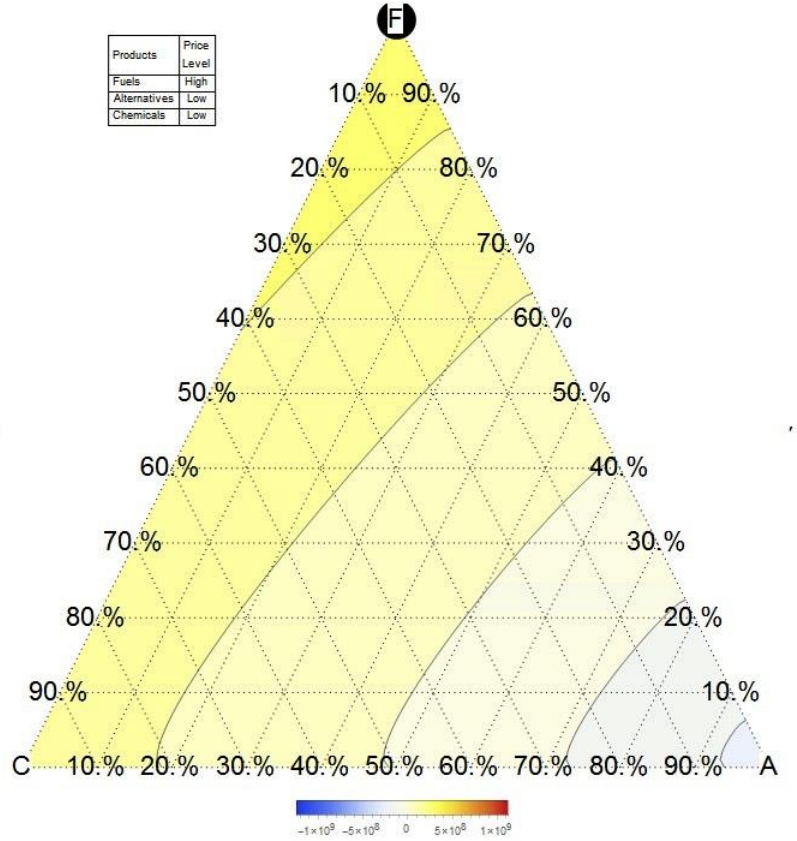

Pyrolysis in Nicaragua

The role of
Iowa State University

With strengths in Mechanical, and Manufacturing Engineering,
Engineering Management, and Renewable Energy Research,

the goal of this initiative is to
focus on the development of the key link in the biofuels supply chain,
the design and development of advanced energy manufacturing technologies to
reduce the cost of biofuel production facilities.


Feedstock
Production


Feedstock
Logistics


Biofuels
Production


Biofuels
Distribution


Biofuels
End Use